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Title: **Fabrication of Conical Mandrel to be Used in Development of Large Diameter Solar Concentrators for Solar Thermal Propulsion (STP) Applications**

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1.0 Scope and Purpose:

The purpose of the overall program is to produce a very large fresnel film lens which will ultimately become a deployable solar concentrator film. This tasked effort will provide two segments of a nickel metal film replicating a surface from a conical mandrel which will represent a significantly far off-axis segment of the final concentrator. The nickel deposition process selected will be performed by Electroformed Nickel, INC of Huntsville AL (ENI). The University of Alabama in Huntsville (UAH) was tasked to produce a conical mandrel suitable for the deposition and replication effort by ENI. Furthermore, United Applied Technologies (UAT) will inspect and evaluate metal films made by ENI prior to additional replication processes for producing the actual substrates to be used for the casting of the plastic films by UAT.

2.0 UAH Task Description:

2.1 UAH has developed the mandrel design and software derived tool path suitable for the single point diamond turning of the conical mandrel. The requested effort is to prepare a 15 degree segment of a 25 foot diameter lens. Therefore an arc of about 3.1 feet at the perimeter of the lens is described. The cone maximum diameter (excluding fixturing) is then about 10 inches.

2.2 UAH provided all designs and the rough machining contracted effort.

2.3 UAH has provided approved drawings in Autocad 13 (advanced) format.

2.4 UAH provided the diamond machining of the master part. UAH provided design interface with UAT and ENI to assure that the design is materially compatible with subsequent operations.

2.5 UAH provided assistance to plate a protective electroless nickel phosphorous coating onto the mandrel to render it durable for the electroforming operations. NASA will provide access to the electroless nickel process used presently for the fabrication of NASA optical component development.

2.6 UAH provided ENI advice in the preliminary nickel deposition processes to assure ENI can produce the proper part from the mandrel.

2.7 UAH acknowledges any proprietary procedures developed by ENI and UAT for the fabrication of large fresnel optics using the conical mandrel as a basis. The development of procedures by UAH for the fabrication of the conical mandrel will be without royalty or licensing fees between ENI, UAT or UAH.

3.0 NASA/MSFC Task Description:

3.1 NASA/MSFC will interface with ENI and UAT to provide appropriate interface to avoid proprietary rights issues.

3.2 NASA/MSFC has provided the preliminary optical prescription for the final fresnel lens. The manner by which the gender of the machined cone was determined based on best machining practice as well as requirements. This includes the fact that machining sharp grooves is more difficult than to machine sharp peaks.

4.0 Technical Progress

4.1 Preliminary Design

The preliminary design of a conical mandrel was made to determine the machining and fabrication aspects of producing a flat replicated segment of a fresnel lens at 12.5 feet off the center. In order to allow the use of the UAH diamond turning center (PNEUMO 2000) a piece no larger than 10 inches diameter and 8 inches length could be mounted on the spindle. Also the weight needed to be minimized in order to avoid vibration and overload of the air spindle. The tool post mount to the stage had to be rotated 90 degrees to accommodate the clearance, requiring machining of the base. The maximum length of the fresnel cut was 5.5 inches. From this constraint set the mandrel was designed from a piece of cylindrical 6061-T6 tube 8.0 inch ID by 10.0 inch OD. The extra length was requested by ENI for subsequent operations since the machine would only traverse 5.5 inches. The end sections were recessed to allow electroless nickel plating and subsequent cutting of the fresnel pattern on the center 5.5 inch optical section only. The design was completed by establishing the start of the fresnel cut closest to the machine as reference. This required that a very small amount of the 12.5 feet radius be lost due to the slope of the part starting at ten inches diameter. At the start of the cut the diameter was necessarily 9.941 inches.

4.2 Final Design

A slot was made lengthwise to allow the deposit to have a split for separation after plating. This in turn required a strip for minimizing the interrupted cut by the diamond tool. The tool path was generated to translate the fresnel pattern from a circular surface to the conical surface. The initial fresnel pattern code for the circular pattern was furnished by UAT. This code was examined for suitability to use the tip of the cutting tool fed in very fine (~ 1 micron) steps versus using the edge to cut a complete groove each step. The decision was to use the fine point feed in spite of potential tip wear. This in turn allowed the true fresnel pattern to be cut accommodating the fact that each groove angle varies slightly. If the edge of the tool was used for the cut then only the average angle could be used without a rotational tool post holder which would be programmed to accommodate the angle change. However the original code provided would not provide all of the information. UAH (James Hadaway) completed the tool path translation for the change from circular to conical but then was confronted with the challenging task of correcting the angle for each fresnel cut by two axis machine control. This he done by writing a separate program outside the contracted time available. The incorporation of the advanced programming then permitted the complete translation of the circular to conical patterns. While this represented an extensive effort it is not required to do this again since the code will permit input of any fresnel design of this nature and will generate the proper tool path for any desired segment. The mandrel dimensions were generated by a commercial plotting program and checked by James using A commercial math package. It became evident that the thickness of the plating and the steps at the edges of the fresnel pattern had to be considered in the design. Again this effort does not require repeating. At this point the complete design of a very large fresnel lens using conical segments for replication mandrels and the mechanical fabrication drawings can be easily produced.

4.3 Fabrication

The mandrel was rough machined using the ID as reference to assist in maintaining balance. The center optical section was diamond machined to assure roundness and surface smoothness. The balance was very good without further counterweights. The surface was plated with electroless nickel of 11% phosphorous alloy to provide a durable surface for the electrolytic nickel electroforms. This was plated to a thickness of 0.011 inch which is more than twice the amount normally used. The plating work was supported by NASA MSFC as proposed with Mitch Menderek, Steve Hudson and Pat Johnson providing the support. Upon returning for the fresnel pattern cutting the roundness was very good at about 0.0005 inch TIR. The balance had to be corrected slightly this time however. The diamond turning of the fresnel pattern took about 24 hours machine time due to the feed pattern developed. Upon completion the tool appeared to be normal in that almost no detectable wear was noted and no chipping occurred. This indicates that a much higher feed rate may be possible. The last cut was at about 0.5 micron feed and as such left a staircase of this dimension. This could also be reduced in future units. The center bar of aluminum was used for the inspection.

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